REVIEW OF RECENT STUDIES OF MOBILE PHONES' HEALTH EFFECTS

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ABSTRACT:-
Concern has arisen that using hand-held mobile telephones and mobile telephone base stations have possible health effects. There have also been numerous public objections to the sitting of TV, radio and cell phone base stations because of a fear of cancer induction. If such a health effects do exist, the matter would be of considerable public health importance, given the rapid increase worldwide in the use of these devices. Motivated by health concerns, a new wave of research has been undertaken in various countries worldwide, searching for possible links between cell phone radiation and health problems. New studies suggest that mobile radiation might double the risk of developing cancer in addition to various other effects. These new studies contradict the previous researches that showed no evidence of the impacts of mobile phones to human health. The goal of this study is to provide a brief overview of the existing RF radiation–health effect studies and the basic precautionary principles.

KEYWORDS:-
Mobile Phone, Radiation, Health Effects, Radio Frequency.

INTRODUCTION
The use of mobile telephones is increasing rapidly, now used by more than 2.4 billion people worldwide, [1]. This significant increase in addition to changing
techniques and an extension of the coverage of reception areas has been accompanied by an upsurge in public concern about the possible hazards of radio frequency field (RF) exposure. Mobile telephones transmit and receive microwave radiation at frequencies of 900 and 1,800 MHz. These radiations have been associated with thermal and non-thermal effects. The power intensity of the electromagnetic fields is measured in units of mW/cm² but this provides little information about the biological consequences unless the amount of energy absorbed is known. Therefore, exposure limits relevant to mobile telephones are expressed in terms of the amount of energy absorbed by a unit mass of the object. This is expressed as the specific absorption rate (SAR), with units of W/kg. International Non-Ionizing Radiation Committee of the International Radiation Protection Association (ICNIRP) published guidelines on exposure limits to electromagnetic fields in the frequency range from 100 kHz to 300 GHz in 1988, [2] and were revised in 1996, [3]. Furthermore, an additional guideline for limiting the exposure to electromagnetic fields was published in 1998, which in particular took into consideration the growing use of phones and the protection of the general public, [4]. Individual countries set SAR guidelines to indicate to the public what level of electromagnetic waves emitted by electrical devices is safe.

Although many epidemiologic researches were conducted several decades ago on RFs in occupational settings, in general the effects of RFs in humans are an emerging area of investigation. In fact, there are conflicting reports relating to possible health effects from RF exposure. The research studies on the impact of mobile phones radiation on health remains inconclusive although it indicate that RF waves affect cells without heating them. This paper summarizes the current state of knowledge about the potential health risks of radiofrequency fields on human health.

TECHNICAL ISSUES
Mobile (cellular) phones are now an integral part of modern telecommunication systems. The operation of mobile telephony is based on two-way radio communication between a portable handset and the nearest base station, every base-station serves a cell. There are three cellular system cell sizes. A cellular system with its cell size of several kilometers is referred to as macro-cell systems and is used in rural areas. The antennas for macro-cells can be mounted on ground-based masts, rooftops or other existing structures. They must be positioned at a height that is not obstructed by terrain or buildings. Macro-cells provide radio coverage over varying distances depending on the frequency used, the number of calls made and the physical terrain. Macro-cell base stations have a typical power output in tens of watts, [5]. A ground-based structure that supports antennas at a height where they can satisfactorily send and receive radio waves is called a mast. A typical mast is 15m high, and of steel lattice or tubular steel construction. New slimmer versions of masts are now available which can be painted to blend in with their surroundings, disguised as trees or used in conjunction with street lighting and CCTV cameras. Masts themselves play no part
in the transmission of the radio waves. Maximum ground level emission or the beam of highest intensity usually occurs between 50m and 200m from an antenna. The ground level emission within this area is the highest circling a base station. Emission levels reduce rapidly as the distance increases from the antenna. The highest emissions levels are directly in front of the antenna, 15m or more off the ground, (see Fig. 1). In addition, the stations have subsidiary beams called side-lobes, into which a small fraction of the emitted power is channeled. Unlike the main beam, these side-lobes are localized in the immediate vicinity of the mast, and, despite their low power, the power density can be comparable with that of the main beam much further away from the mast. In densely populated areas, micro-cells provide additional coverage and capacity where there are high numbers of users within urban and suburban macro-cells.

The antennas for micro-cells are mounted at street level, typically on the external walls of existing structures, lamp-posts and other street furniture. They are smaller than macro-cell antennas and, when mounted on existing structures, often blend in with building features to minimize visual impact. Micro-cells provide radio coverage over distances, typically between 300m and 1000m and have lower output powers compared to macro-cells, usually a few watts. When cell sizes are reduced below about 100 m covering areas such as large rooms, corridors, underground stations, large shopping centers, and so on, cellular systems are sometimes referred to as pico-cell systems with antennas mounted below rooftop levels or in buildings. As the user of a mobile phone moves from cell to cell, the call is transferred between base-stations without interruption. An important feature of the mobile phone technique is the adaptive power control that ensures that the communication can be carried out without unnecessarily high power. This technique complicates the exposure assessment.

Mobile phone systems operate at several frequencies in the RF band, (see Fig. 2), either near 900 MHz (utilized in Palestine) or near 1800 MHz; the corresponding wavelengths in air are 33 and 16 cm. The utilized frequency band is divided into two regions: The uplink band (890 to 915 MHz) which is used by the mobile phones and the downlink band (935 to 960 MHz) which is used by base stations,
The signals transmitted by Jawwal towers are within the frequency band (955.2 to 960 MHz) while the signals transmitted by phones are within the frequency band (910.2 to 915 MHz).

**Rf-Radiation Dose and its Measurements**

In contrast to X-ray energy, RF energy is nonionizing, (see Fig. 2), because the energy of the quanta that carry the energy is insufficient to knock electrons from atoms (the mechanism for injuries from ionizing radiation), [7, 8].

The energy flux or power density \( P \) (in W/m\(^2\)) across a surface measures the strength of an incident EM wave and is given by the relationship:

\[
P = \text{Re}(\hat{n} \cdot S) = \text{Re}[E \times H^*]
\]

where \( S \) is the complex (i.e. frequency domain) Poynting's vector in W/m, \( \hat{n} \) is a unit vector perpendicular to the surface in question, \( E \) is the complex electric field strength in V/m, and \( H^* \) is the complex conjugate of the complex magnetic field strength in A/m. Unfortunately, power density is an imperfect indicator of the relevant conditions inside an irradiated organism. Instead, scientists specify a metric of internal exposure, specific absorption rate, SAR (in W/kg). The SAR is generally used as the dose metric in laboratory experiments. For typical biological tissue, the SAR is given by

\[
SAR = (E_{local})^2 \times \frac{\sigma_{eff}}{\rho}
\]

where \( E_{local} \) is the r.m.s. electric field (V/m) in the organism at the point of interest, \( \sigma_{eff} \) is the effective conductivity in S/m, and \( \rho \) is the local mass density in kg/m\(^3\). SAR is estimated in three ways:
1. Small antennas can be used to determine the local electric field in tissue, and if $\sigma_{\text{eff}}$ is known, the SAR can be computed.

2. Using miniature thermal probes. RF radiation causes heating of tissue which can be detected and used to infer the SAR in the neighborhood of a temperature probe. In a medium with spatially homogeneous SAR,

$$\text{SAR} = c_p \frac{\delta T}{\delta t}$$

where $c_p$ is the specific heat at constant pressure in J/(kg·K), and $\delta T$ is the change in tissue temperature over a time $\delta t$. In principle, SAR determination is as simple as turning on the RF-radiation source and measuring the temperature change as a function of time. Unfortunately, heat diffuses, and spatially non uniform SAR can, over the time needed to produce a measurable temperature offset, be significantly confounded by thermal diffusion.

3. Using electromagnetic numerical modeling techniques. Fortunately, the numerical modeling of macroscopic bodies is well-developed and offers a way around the obstacles to experimental determination of SAR. Given an organism and well-characterized irradiation geometry, finite difference time domain (FDTD) simulations can predict SAR. For geometries within which robust field measurements can be made, FDTD predictions actually work when tested, [9], however, it can be time consuming and expensive.

**PRECAUTIONARY PRINCIPLE**

According to the World Health Organization, the Precautionary Principle is "a risk management policy applied in circumstances with a high degree of scientific uncertainty, reflecting the need to take action for a potentially serious risk without awaiting the results of scientific research." The World Health Organization has recommended that the precautionary principle could be voluntarily adopted in this case of mobile phone radiation, [10]. It follows the recommendations of the European Community for environmental risks. Other less stringent recommended approaches are prudent avoidance principle and ALARA (As Low as Reasonably Achievable), [11]. The most stringent Precautionary Principle (for "uncontrolled environments") of the ANSI/IEEE C95.1, [12] recommendations for average external exposure to UHF is

$$P = \frac{f \ (\text{in} \ Hz)}{1.5 \times 10^8} = 2 \text{ to } 20 \ W / m^2 = 0.2 \text{ to } 2.0 \ mW / cm^2$$

Federal Communications Commission in USA in 1996, [13], Health Canada in 1999, [14], and in most European nations (International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 1998, [2], issued exposure guidelines that are designed to protect against all identified hazards of RF energy. As a practical matter, RF energy levels are below public exposure guidelines at all
In response to public concerns about possible health effects of mobile base stations, several European countries (Slovenia, Italy, and most recently Switzerland) have instituted strict limits for RF exposure from transmitters, based on the precautionary principle. The exposure limits are far below international exposure guidelines. China has instituted a new strict standard that would cap handset radiation emissions at half the levels allowed by ICNIRP. The Precautionary Principle involves recommendations such as the minimization of mobile phone usage, the limitation of use by at-risk population (such as children), the adoption of mobile phones and microcells with ALARA levels of radiation, the wider use of hands-off and earphone technologies such as Bluetooth headsets, the adoption of maximal standards of exposure, RF field intensity and distance of base stations antennas from human habitations, and so forth. The responsibility for complying with the recommended exposure limits lies with the manufacturers. Radio waves transmitted by mobile telephones do not exceed the SAR limits because all modern GSM mobile telephones, irrespective of the manufacturer, emit a level of radio waves that produces a SAR for the head within the recommended exposure limits.

THERMAL EFFECTS
Heating of biological tissue is a consequence of microwave energy absorption that caused the rise in temperature. The force produced by an electric field on charged objects, such as the mobile ions present in the body, causes them to move, resulting in electric currents, and the electrical resistance of the material in which the currents are flowing results in heating. This heat input causes the temperature to rise and it continues to do so until the heat input is balanced by the rate at which it is removed, mostly by blood flowing to and from other parts of the body. It is estimated that it takes several minutes from the moment RF exposure occurs for the irradiated parts of the body to reach their final equilibrium temperatures. In view of this slow response, the equilibrium temperature arising from the oscillating fields of mobile telecommunications will essentially be determined by the average power absorbed, [17]. It has not yet proved possible to measure the small changes in temperature directly, except those at the outer skin, [18] and, although temperature is a more direct determinant of thermally induced tissue damage, the majority of theoretical studies up to the present time have restricted themselves to the computation of SAR alone.

The relationship between the SAR and the resulting temperature rise is complex, and significantly dependent on antenna configuration, location and frequency. In a recently published study, [19], the heat deposition within the head was computed by coupling a Finite Difference Time Domain model for SAR with a new thermal model. The thermal model includes the convective effects of discrete blood vessels, whose anatomy was determined using magnetic resonance
angiography of a healthy volunteer. For a 915 MHz dipole antenna with a time-averaged power output of 0.25 W (equivalent to a typical mobile phone), this study results in an SAR of about 1.6 W/kg and predicts a maximum brain temperature rise of 0.11°C in the steady state.

Amongst the most thermally vulnerable areas of the body, because of their low blood supply, are the eyes and the testes. The cornea of the eye does not have the temperature regulation mechanism. Premature cataracts are known as an occupational disease of engineers who work on high power radio transmitters at similar frequencies. Lowering of male fertility is a well-documented acute exposure hazard. Due to the low power of mobile phones, cataracts and reduced sperm counts have not been reported to occur in users.

It has been claimed that some parts of the human head are more sensitive to damage due to increases in temperature, particularly in anatomical structures with poor vasculature, such as nerve fibers. More recent results from a Swedish scientific team at the Karolinska Institute, [20], have suggested that continuous use of a mobile phone for a decade or longer can lead to a small increase in the probability of getting acoustic neuroma, a type of brain tumor. The increase was not noted in those who used phones for less than 10 years. An interphone case-control study in five North European countries suggests that there is no substantial risk of acoustic neuroma in the first decade after starting mobile phone use. However, an increase in risk after longer term use or after a longer lag period could not be ruled out, [21]. Another study conducted by the Swedish National Institute for Working Life supported an increased risk of malignant tumors on the side of the head the phone is used, [22]. Such long term heavy use involved phones of older higher power analog designs; that were first introduced to Sweden in 1984, earlier than many other countries. Other studies found that no relation for risk of glioma brain tumors, acoustic neuromas, salivary gland tumors, eye tumors, leukemias or cancer, [23, 24,25], and use of mobile phone.

NON-THERMAL EFFECTS
The communications protocols used by GSM phones result in low-frequency pulsing of the carrier signal. These low frequencies are similar to those that exist in the electrical oscillations of the human body, specifically the alpha and delta brain waves. This gives possibility that low-intensity microwave radiations from mobile system can exert subtle, non-thermal influences on a living organism. Thus some endogenous biological electrical activities can be interfered with via oscillatory aspects of the incoming radiation, [26]. The biological electrical activities that are vulnerable to interference from GSM radiation include highly organized electrical activities at a cellular level whose frequency happens to lie in the microwave region. The intensity of radiation needed for this recognition is many orders of magnitude below even that currently associated with non-thermal effects. However, no experimental results have indicated this theoretical possibility. In the other hand, non-thermal effects could be reinterpreted as a normal cellular
response to an increase in temperature as noted by Glaser, [27]. Glaser has argued that there are several thermo receptor molecules in cells, and that they activate a cascade of second and third messenger systems, gene expression mechanisms and production of heat shock proteins in order to defend the cell against metabolic cell stress cause by heat.

A recent pan-European study named REFLEX, (Risk Evaluation of Potential Environmental Hazards From Low-Energy Electromagnetic Field Exposure Using Sensitive in vitro), involving 12 collaborating laboratories in several countries showed some compelling evidence of DNA damage of cells in in-vitro cultures, when exposed between 0.3 to 2 W/kg. There were indications, but not rigorous evidence of other cell changes, including damage to chromosomes, alterations in the activity of certain genes and a boosted rate of cell division, [28]. The results of this study run contrary to many similar studies that were conducted before and showed no increase in DNA damage, [29]. Furthermore, a recent UK National Radiation Protection Board published review criticizes the REFLEX project findings, [30].

ELECTROMAGNETIC HYPERSENSITIVITY SYNDROME
Hypersensitivity to electromagnetic fields (EMFs) is a fairly new phenomenon, and etiology of the hypersensitivity to EMFs is not yet known.

Many users of mobiles, computers, or electrical appliances have reported feeling several unspecific symptoms during and after its use. Such symptoms are burning and tingling sensations in the skin of the head and extremities, fatigue, sleep disturbances, dizziness, and loss of mental attention, reaction times and memory retentiveness, headaches, malaise, heart palpitations and disturbances of the digestive system, [31]. Some researchers have named this syndrome as a new diagnostic entity, EHS or ES (electro sensitivity). A recent study found that five percent of the Swiss population attributes symptoms to EMF. General practitioners might play a key role in recognizing an emerging health risk, since they are the first to observe and follow up persons who attribute symptoms to EMF, [32].

The World Health Organization names it "idiopathic environmental intolerance". The International Commission for Electromagnetic Safety (ICEMS) in its annual meeting in September 2006 concluded that more evidence has accumulated suggesting that there are adverse health effects from occupational and public exposures to EMF at current exposure levels, [33].

HEALTH HAZARDS OF BASE STATIONS
The number of base stations which communicate with the mobile phones has increased sharply as technology progresses and data demands have increased on the mobile network. The buildup of networks has sparked many health concerns
and much community outrage since the antennas of the base station radiate electromagnetic wave continuously. Fortunately field intensities drop rapidly and decrease as a function of the square of distance. A recent study found a variety of health effects for people living within 300 m of base stations. Fatigue, headache, sleep disruption and loss of memory were among the effects found, [34].

Many measurements and experiments have shown that transmitter power levels are relatively low in modern GM 2G antennas, [16]. The Australian Communications Authority and Australian Radiation Protection and Nuclear Safety Agency recently announced that the 3G towers actually cause less radiation than the already present 2G network. Furthermore, the propagation of more towers may add to a more strongly irradiated area. However, it can result in lower radiation for the mobile phone user, since phones transmit at a lower power when closer to a base station.

**GENERAL CONCLUSIONS AND RECOMMENDATIONS**

The research study on the effect of the exposure to mobile phones radiation on health is inconclusive. A major concern is that the lag periods that have been examined to date are necessarily short. The implication is that if a longer lag period is required for a health effect to occur, the effect could not be detected easily. Only in the few countries where mobile phones were introduced very early has it been possible to look at use for more than 10 years. Furthermore, children who are increasingly heavy users of mobile phones have not been included in any study, with the exception of studies of people living near radio and TV antennas. They may be particularly susceptible to harmful effects and they are likely to accumulate many years of exposure during their lives.

Results of epidemiologic studies to date give no consistent or convincing evidence of a causal relation between mobile phone radiation exposure and brain tumor. On the other hand, these studies have too many deficiencies to rule out an association.

Recent researches demonstrate that mobile phones can affect cells without heating them that sparked a new wave of research on the non thermal effect of RF radiations. The new research results raise the question about the effectiveness of the international exposure guidelines that made many countries to institute new guidelines for better human protections based on the precautionary principle.

The World Health Organization and the International Commission for Electromagnetic Safety acknowledged the “idiopathic environmental intolerance” caused by the RF radiations. There are some concerns that there are adverse health effects from occupational and public exposures to EMF at current exposure levels

The radiation levels from base stations are weak in general therefore the possibility that it would create a health hazard is low, however this possibility is a concern for many people. To date no conclusive study on any outcome has been published on this.
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